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MASK EXPOSURE DEVICE
[Masuku rokou souchi]

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SPECIFICATION

1. Title of the Invention

MASK EXPOSURE DEVICE

2. Claims

1. With respect to a mask exposure device in which mask exposure is carried out by converging and irradiating a light flux from an optical source used for mask irradiation and by projecting the image of said mask onto a wafer by means of an optical system, a mask exposure device characterized by adjusting the exposure time by providing a shutter, which is for controlling the mask irradiation time, and a photodetecting means, which is for detecting reflected light from the wafer, by then calculating the exposure time by using the light intensity of said reflected light, and by then operating said shutter accordingly.

2. A mask exposure device of Claim 1 characterized by correcting the exposure time by measuring the development size of the resist obtained as a result of a wafer developing process in addition to the above-mentioned light intensity of the reflected light during the above-mentioned calculation of the exposure time.

3. A mask exposure device of Claim 1 characterized by the above-mentioned mask exposure device being comprised of a projection exposure device.

4. A mask exposure device of Claim 1 characterized by the optical system, which projects the image of the above-mentioned mask onto the wafer, being comprised of a reducing projection lens.

5. A mask exposure device of Claim 1 characterized by the above-mentioned photodetecting means being comprised of a photosensor.

6. A mask exposure device of Claim 1 characterized by the above-mentioned photodetecting means performing measurement by guiding at least part of the light inside the irradiated-light path to a photosensor by means of a light extractor.

3. Detailed Explanation of the Invention

[Field of Industrial Application]

The present invention pertains to mask exposure devices suitable for the manufacture of integrated circuits in which an ultrafine processing technique is utilized.

[Related Art]

As mentioned in Kokai No.59-161027, the optical source of a conventional device is controlled by providing an illuminance control device in order to stabilize the exposure illuminance on a wafer. However, nothing has been mentioned regarding the correction of the large fluctuations of the optical energy absorbed by the wafer having a resist applied to it that are caused by fine fluctuations of the thickness of the resist-coated film.

[Problems that the Invention is to Solve]

In order to stabilize the exposure illuminance on the wafer, the amount of light from the optical source is controlled by providing a sensor that monitors the illuminance in an area just proximal to the mask, etc., by thus directly obtaining the amount of light from the optical source, and by then comparing it with a set value.

However, even if the amount of light illuminated on the resist film of the wafer is controlled to be constant, the resist's development size does not necessarily stay constant. This is because, since the reflectance on the resist surface changes greatly as a result of even a change of about 0.02μm in the resist film and since the energy actually absorbed into the resist thus changes greatly, the degree of exposure of the resist varies greatly, resulting in fluctuations of the development size.

Therefore, in order to prevent this, it is necessary to stabilize the value which is obtained by subtracting the amount of light reflected from the resist surface from the illuminance amount, in other words, the amount of light (exposure amount) that is actually absorbed by the resist film.

The purpose of the present invention is to supply a mask exposure device capable of reducing the variation in the development size by making corrections in accordance with the fluctuations of the rate of energy absorption into the resist film caused by fine fluctuations of the resist film's thickness.

[Means for Solving the Problems]

The above purpose can be achieved by providing an optical detector, or an optical guide path leading to an optical detector, inside the irradiated-light path of a mask exposure device, by thus detecting light reflected from the wafer having a resist coated to it, by calculating the change in the rate of light being absorbed into the resist film by using the obtained value, and by correcting the exposure (light irradiation) time in accordance with the change.

[Operation of the Invention]

By applying a resist to the wafer in the thickness of about 1μm, by exposing a mask pattern, and by developing the wafer by using a developer, a pattern similar to the mask pattern becomes formed in the resist. If a positive resist is utilized and the exposure time is made to be shorter than the reference value, the developed size of the resist line tends to become thicker, and if the time is made to be shorter, said line tends to become thinner. Incidentally, even a change of about 0.02μm (about 2% of the reference film thickness) in the thickness of the resist-coated film from the reference value causes the resist's development size to fluctuate greatly. This is due to the following reason. Even a fluctuation of about 2% in the resist's film thickness causes the reflectance of the resist's surface to increase or decrease by about 10%. As a result, the amount of energy actually absorbed into the resist film is reduced (or increased), which has the same effect as a reduction (or increase) in the exposure time.

Therefore, it becomes possible to obtain a pattern of a preferred development size by detecting the light reflected from the wafer by means of a photodetecting means and by then using the obtained value to control the exposure time in accordance with a change in the resist film.

[Embodiments of the Invention]

In the following, one embodiment of the present invention will be explained by using Fig. 1. Light emitted from the optical source [1] becomes reflected on a reflecting mirror [2] and then becomes converged into parallel beams by means of a condensing lens [5]. These beams are irradiated

onto a mask [6] (reticle) provided with a circuit pattern, and the image of the mask [6] becomes projected onto the wafer [8] by means of a projection lens [7]. The irradiation (exposure) time for the wafer [8] is adjusted by controlling the opening/closing time of a shutter [9] by means of a shutter control device [4].

In the following, the general relationship between the exposure time and the absorption rate will be explained. If the absorption rate of the wafer obtained when a resist having the reference thickness is applied is A_0 and if the reference exposure time at that time is t_P, the following equation indicates the correction value, t'_P, of the exposure time that is obtained when the wafer's absorption rate changed to A_1 as a result of the resist film's thickness fluctuating from the reference value.

$$t'_P = t_P \cdot (A_1 / A_0)^{-1} \qquad \cdots\cdots\cdots (1)$$

Moreover, the absorption rates, A_1 and A_0, of the wafer can be calculated by measuring the wafer irradiation intensities, I_{P0} and I_{P1}, and the intensities, I_{r0} and I_{r1}, of the light reflected from the wafer by using the photosensors provided inside the optical path of the mask exposure device, and they can be expressed as follows.

$$A_0 = (1 - I_{r0} / I_{P0}) \qquad \cdots\cdots\cdots (2)$$

$$A_1 = (1 - I_{r1} / I_{P1}) \qquad \cdots\cdots\cdots (3)$$

Here, I_{P0} and I_{r0} are the irradiation intensity and reflectance intensity, respectively, obtained with respect to the wafer when the thickness of the resist is the reference thickness, and I_{P1} and I_{r1} are the respective intensities obtained when the resist film fluctuated. By performing exposure by using the exposure time, t_P', calculated by the

equation (1), the development size can be prevented from fluctuating.

In Figure 1, the exposure time, t_{P1}, is calculated by an exposure time calculator [10] by using an exposure time setting value, T_P, input from an input device [13], the intensity, I_P (measured by means of a photosensor [12]), of the irradiation onto the wafer [8], and the intensity, I_r (measured by the photosensor [11]), of the reflection from the wafer [8]. The value is then transmitted to the shutter control device [4], which controls the shutter [9] to be opened and closed during this exposure time, t_{P1}. Based on the equation (1), t_{P1} can be expressed as follows.

$$t_{P1} = T_P \cdot (1 - I_{r0} / I_{P0}) / (1 - I_{r1} / I_{P1}) \quad \cdots (4)$$

In this case, I_{r0}, I_{P0}, I_{r1}, and I_{P1} are the same values as those used in the equations, (2) and (3).

In Fig. 1, a photosensor [3] is provided above the optical source [1]. This sensor is used to measure a decrease in the intensity of light emitted from the optical source [1] with the passage of time. When the intensity of light emitted from the optical source decreases, the energy of irradiation onto the wafer [8] decreases, which has the same effect as that which is obtained when the exposure time is shortened, even if the exposure time (controlled by the opening and closing times of the shutter [9]) is constant. Therefore, it is necessary to make a correction in order to keep the irradiation energy applied to the wafer constant.

When the initial light-emission intensity of the optical source [1] is I_{li} and if the light-emission intensity after a certain time has passed is I_{l1}, the correction value, t_{P2}, is expressed as follows.

$$t_{P2} = t_{P1} \cdot (I_{\ell 1} / I_{\ell 2}) \quad \cdots\cdots\cdots (5)$$

$$= T_P \cdot (I_{\ell 1} / I_{\ell 2})(1 - I_{r0} / I_{P0})(1 - I_{r1} / I_{P1}) \quad \cdots\cdots\cdots (6)$$

This calculation is carried out by inputting the value of the measured light-emission intensity of the optical source [1] into the exposure time calculator. According to this embodiment, it is possible to prevent the occurrences of fluctuation in the development size, which are caused by fluctuations of the energy absorbed by the wafer [8] and fluctuations of the light-emission intensity of the optical source. Therefore, there is an effect in that the production yield of integrated circuits can be improved.

The above-described exposure time calculation is carried out by the exposure time calculator [10], the internal structure of which comprises a central processing unit (CPU) [101] and an input/output interface (I/O) [102] in the same manner as the structure of a conventional electronic computer. The input values are the optical-source intensity, reflected-light intensity, and exposure time setting value, and the output value is the exposure time.

Figure 2 is another embodiment of the invention. Its differences from Fig. 1 are the photosensors, [14], [15], [16], and [17], that have been added. According to this embodiment, the irradiation and reflected-light intensities can be measured below and above the mask and can also be measured above the condensing lens. Therefore, it is possible to select sensors appropriate for the type of the wafer and the type of the mask, and they can be utilized independently or the average value

of the outputs of multiple pieces can be utilized. This embodiment has the effect of accurately measuring the fluctuations in the absorption.

Figure 3 shows another embodiment of the invention. Its difference from Fig. 2 is the fact that the photosensors, [12], [15], and [17], have been removed. In the case of this embodiment, by using the fact that the wafer irradiation intensity is proportional to the light-emission intensity of the optical source [1], the wafer irradiation intensities, I_{P0} and I_{P1}, of the equation (6) are made to be values obtained by multiplying the measured value of the light-emission intensity of the optical source by a correction coefficient, k_P. In other words, I_{P0} and I_{P1} can be expressed by the following equations.

$$I_{P0} = k_P \cdot I_{l0} \qquad \cdots\cdots\cdots (7)$$

$$I_{P1} = k_P \cdot I_{l1} \qquad \cdots\cdots\cdots (8)$$

Here, I_{l0} is the light-emission intensity of the optical source [1] obtained when the wafer coated with a resist having the reference thickness is exposed, and I_{l1} is the light-emission intensity of the optical source [1] obtained when the wafer coated with a resist having an arbitrary thickness is exposed. According to this embodiment, the intensity of reflected light from the wafer is measured by using at least one of the photosensors, [11], [14], and [16]. The measurement accuracy can be improved by carrying out the measurements by using multiple sensors and by using the average value.

The exposure time, t_{P3}, of this embodiment can be expressed as follows.

$$t_{P3} = T_P \cdot (I_{\ell 1} / I_{\ell 1})(1 - I_{r0} / k_P I_{\ell 0}) / (1 - I_{r1} / k_P I_{\ell 1}) \qquad \cdots\cdots\cdots (9)$$

Here, k_P is the correction coefficient.

This embodiment has the effect of reducing the number of the photosensors and of thus reducing the cost.

Figure 4 shows another embodiment of the invention. It is different from Fig. 3 in that the development size of the resist determined in a wafer developing process [19] is measured by means of a development size measuring device [20] and also in that the measured value is input to the exposure time calculator [10] in order to correct the exposure time. If the correction coefficient obtained at this time is k_q, the corrected exposure time, t_{P4}, is expressed by the following equation. [18] is a component of the optical system of the exposure device.

$$t_{P4} = k_q \, t_{P3} \qquad \cdots\cdots (10)$$

$$h_q = 1 + \alpha \, (x_\ell - x_s) \qquad \cdots\cdots (11)$$

Here, x_l is the resist development size, x_s is the resist development size setting value, and α is the correction coefficient.

According to this embodiment, compensations can be made for even fine fluctuations in the conditions of the developing process. Therefore, it has an effect of improving the production yield.

Figure 5 shows another embodiment of the present invention. Its differences from Fig. 1 are in that the photosensor [11] is placed outside, instead of inside, of the optical path and in that the light inside the

optical path is lead to the photosensor [11] by a light extractor [21]. According to this embodiment, the light extractor [21] can be reduced in size, and therefore, there is an effect in that shades will not be cast on the mask projection image.

[Effects of the Invention]

According to this invention, corrections can be made in response to fluctuations of the rate at which energy is absorbed into the resist film which are caused by fine fluctuations in the thickness of the resist film located on the wafer. Therefore, there is an effect in that it is possible to provide a mask exposure device capable of reducing fluctuations in the resist's development size.

4. Brief Explanation of the Drawings

Figure 1 is a drawing showing one embodiment of the basic structure of the invention. Figure 2 through Figure 5 are drawings showing the other embodiments of the invention. Figure 6 is a drawing showing the internal structure of the exposure time calculator.

[1] = optical source; [4] = shutter control device; [6] = mask; [7] = projection lens; [8] = wafer; [9] = shutter; [10] = exposure time calculator; [11], [12], [14], [15], [16], [17] = photosensor; [21] = light extractor; [20] = development size measuring device.

Figure 1

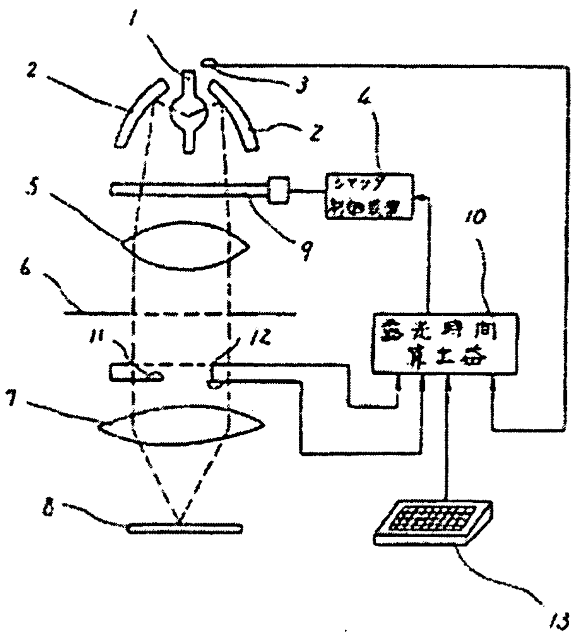
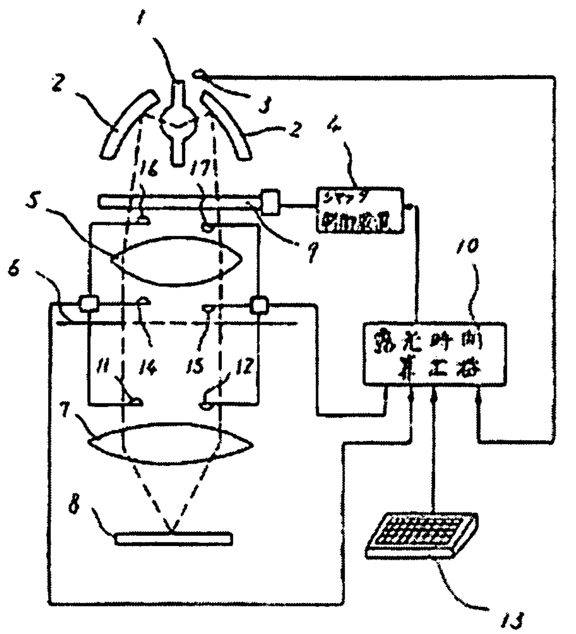


Figure 2

第 2 図



Key: 1)optical source; 4)shutter control device; 6)mask; 7)projection lens; 8)wafer; 9)shutter; 10)exposure time calculator; 11)photosensor; 12)photosensor.

Figure 3

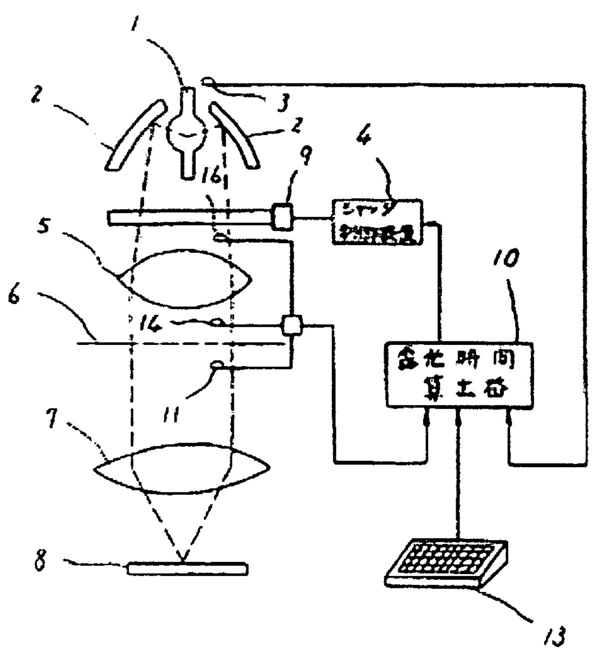
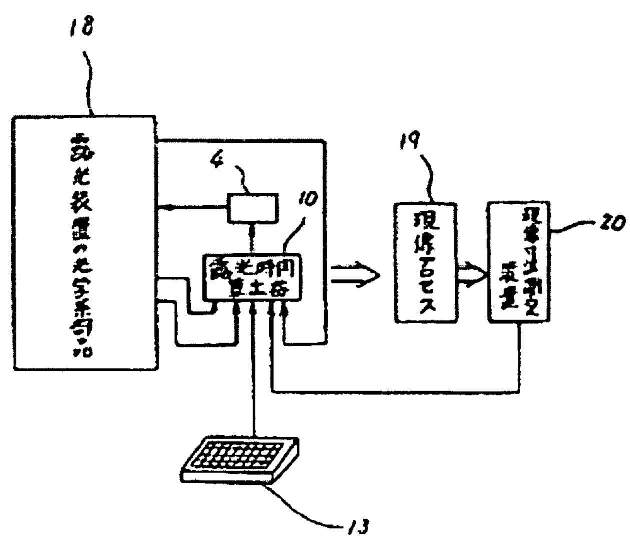


Figure 4

第 4 図



Key: 4)shutter control device; 10)exposure time calculator; 18)optical-system component of exposure device; 19)developing process;

20)development size measuring device.

Figure 5

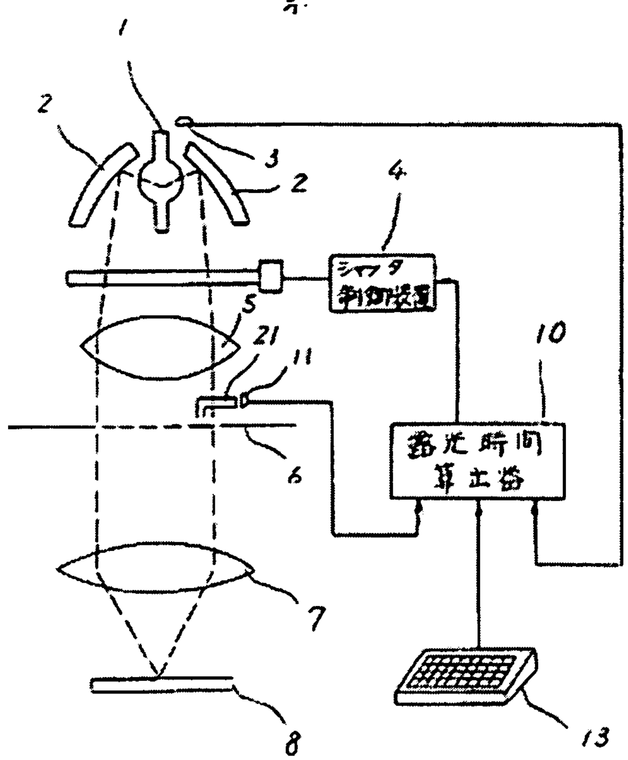
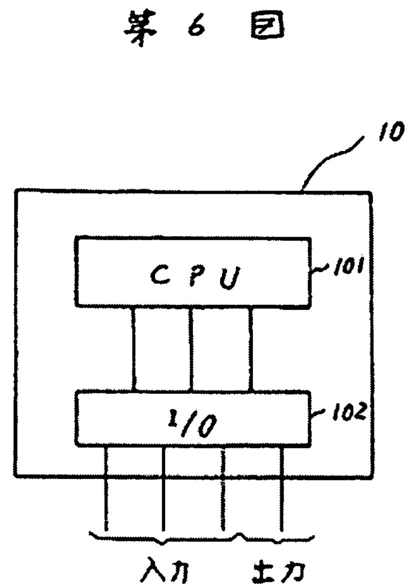


Figure 6



Key: 4)shutter control device; 10)exposure time calculator; a)input; b)output.